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Summary of Available Literature Regarding High Flow Fish Passage Systems

Existing design criteria for protection of salmonid fry at water control projects requires that dewatering screens be designed to ensure that water velocities approaching the screen face not exceed 0.40 feet per second (fps). Use of existing fish protection criteria for a conventional dewatering facility designed to handle high flow volumes (~20,000 cfs) would require a screen area of 50,000 square feet. The sheer size of such a dewatering facility would present significant construction and operational difficulties. High velocity technology offers a potential alternative to conventional dewatering facilities.

Eicher screens and modular inclined screens (MIS) have been successfully developed employing velocities in the channel approaching the screen face exceeding 4.0 fps. These high velocity dewatering technologies have been successfully used at several projects in the Pacific Northwest, but the process is still considered experimental. In order to evaluate application of high velocity technology to a high volume dewatering facility on the lower Columbia River, we conducted a literature search for relevant hydraulic and biological studies of high velocity dewatering systems. The following report summarizes available information on existing and proposed projects that have developed or used high velocity dewatering technology to protect juvenile salmonids.

1.0 ELWHA DAM PROJECT

The Elwha Dam, located near Port Angeles, Washington, was the site of extensive testing of an Eicher screen in 1990 and 1991. The Electric Power Research Institute (EPRI) contracted with Stone & Webster (personnel now with Alden Research Lab) to conduct the biological evaluation. Hosey & Associates Engineering Company (now Harza Northwest) designed the Eicher screen for the project and participated in scale model and field testing.

The Eicher screen prototype was installed in a 9-ft diameter penstock to one of four 3.2 MW hydropower units. The elliptical screen was inclined about a horizontal axis from front to rear at an angle of about 16°. The screen was composed of three panels of wedgewire material. The inclined portion of the screen was comprised of two sections with a uniform bar width of 0.073 inch (1.9 mm), but with bar spacing of 0.25 inch (3.2mm) at the upstream end and 0.035 inch (0.9 mm) spacing at the downstream end. This differential bar spacing resulted in a screen porosity of 63 % at the upstream end and 32 % at the downstream end. The inclined portion of the screen was 27.5 feet long with an area of 178.2 square feet. The bypass transition screen was 7.0 feet long and constructed of 0.093 inch (2.4 mm) wedgewire material with a bar spacing of 0.008 inch (0.2 mm) to achieve a porosity of 8 %. A small diameter outlet at the top of the penstock near

the downstream end of the Eicher screen passed fish screened from the main flow into a 24 inch diameter pressure bypass pipe. Operating capacity of the fish bypass entrance section was about 25 cfs at a penstock flow of 500 cfs, or roughly 5 percent of the total flow into the intake.

Screen effectiveness was evaluated by determining the proportion of fish diverted live, the proportion injured during passage by the screen, and survival four days after screen passage. Penstock velocities ranging from 4.0 to 7.8 fps were evaluated and bypass velocities ranged from 4.0 to 8.6 fps.

The results of testing showed high passage survival for coho smolts [98.7%; 5.7 in (145 mm) average length], as well as steelhead smolts [99.4%; 6.9 in (174 mm) average length] and chinook fingerling smolts [98.8%, 3.9 in (99 mm) average length]. Testing conducted with smaller salmonids also showed good passage survival for chinook pre-smolts [99.9%; 2.9 in (73 mm) average length], steelhead fry [97.1 %; 2.1 in (52 mm) average length] and coho fry [91.6%; 1.7 in (44 mm) average length]. At penstock velocities of less than 7 fps, the passage survival of coho fry was 95.9%. Survival estimates of coho fry at penstock velocities of 7 fps and higher dropped as low as 85.5 %; however the results were compromised by observed sub-lethal effects of immersion stains used to mark control and release lots.

Injuries were generally rare in tests conducted at penstock velocities of 7 fps or less. For all species and lifestages tested except chinook smolts, the proportion of fish with > 16% scale loss on one side ("descaled" as defined in criteria used on the Columbia River) averaged less than 1 % at velocities of 4 and 6 fps, less than 2% at 7 fps, and less than 6% at 7.8 fps. Descaling was most common on chinook smolts, which averaged 0.4 % at 4 fps, 2.8 % at 6 fps, 6.7 % at 7 fps and 12.6 % at 7.8 fps. Most of the injuries appeared to be caused by fish contacting the screen in a localized area where the screen transitions from 63% to 32% porosity. Minor changes in the design of the screen were identified that could reduce or eliminate injury by providing a more even distribution of flow through the screen.

Injury rates increased substantially when the screen was partially clogged with introduced debris. However, the screen was readily cleaned by rotating it approximately 8°. In over 60 days of testing performed at Elwha, natural debris accumulation over the 8 to 12 hour test periods never caused a noticeable increase in injury or necessitated cleaning of the screen. The prototype screen was not operated during fall storms which might have produced a higher natural debris load.

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2.0 ALDEN RESEARCH LABORATORY - 1994-6 BIOLOGICAL / HYDRAULIC MODELING OF THE MIS

The Electric Power Research Institute (EPRI) and Alden Research Laboratory (ARL) have been developing and testing a high velocity bypass system known as the Modular Inclined Screen (MIS). The MIS consists of an entrance with trash racks, dewatering stop log slots, a wedgewire screen set at a 15 degree angle to the flow, and a bypass for directing diverted fish to a transport pipe. The screen is composed of 50 % porosity Hendrick profile bar material with a 0.8 inch (1.9 mm) spacing and is mounted on a pivot shaft so that it can be cleaned by backflushing.

The MIS design is the result of multiple hydraulic studies and scale model tests conducted at ARL. A small flume was initially used to study local velocity variations associated with various support member configurations. A second model, at a 1:6.6 scale, was constructed to evaluate overall flow characteristics such as entrance effects, head losses and bypass configurations. A third test facility, consisting of a 1:3.33 version of the entire MIS, was constructed for further

flow evaluations and biological testing. The screen in a full-scale MIS would be 30 feet in length by 10 feet in width. The effective area of the screen would be 250 sq. ft., with a capacity to screen up to 1,000 cfs at 10 fps. The MIS is designed to be built in modular form with additional modules added to handle increased capacity if needed.

The biological evaluation of the MIS was conducted in the laboratory with juveniles of eleven fish species. Fish passage was evaluated at five velocity increments ranging from 2 to 10 fps. Net passage survival with a clean screen typically exceeded 99% at velocities up to 6 fps for most species, and exceeded 99% overall (all velocities combined) for channel catfish, coho salmon, brown trout, and Atlantic salmon.

Mean net passage survival for rainbow trout juveniles [2.6 in (66 mm) average length] and fry [1.9 in (48 mm) average length] tested in 1992 exceeded 97.8 % for all velocities combined. When velocities were increased from 8 fps to 10 fps, mean net survival for rainbow trout dropped from 97.1 % at 8 fps to 90.9 % at 10 fps. During 1992 tests, 82.5 % of all recorded impingements occurred along the transition wall screen edges. The screen edges were subsequently modified and no impingements were observed at these areas during tests conducted in 1993. Mean net passage survival still dropped when velocities were increased from 8 fps to 10 fps for the four salmonid species tested after the screen modification, but the drop in survival was much less than observed in 1992. Mean net passage survival for the four salmonid species tested in 1993 dropped from 99 % at 8 fps to 97.9 % at 10 fps.

Fish passage tests with debris accumulation demonstrated that incremental increases in screen head loss can cause fish passage success to decline. Debris-induced incremental head losses were greater for deciduous leaves and aquatic vegetation than for equal weights of pine needles. Declines in net passage survival were more dramatic and reached lower levels for rainbow trout fry tested with deciduous leaves and aquatic vegetation than with pine needles. Net passage survival of chinook salmon decreased from 100.0 % to levels less than 90.0 % when incremental head loss reached 0.25 ft at a module velocity of 6 fps and 0.2 ft at a velocity of 8 fps. Backflushing to remove debris was more effective on deciduous leaf debris and aquatic vegetation than pine needles. Head losses due to residual pine needles after backflushing ranged from 0.01 ft at a module velocity of 2 fps to 0.18 ft at 8 fps.

On the basis of the results of clean and debris-laden screen tests, EPRI, Niagara Mohawk Power Corporation (NMPC) and their contributors have constructed a prototype MIS at NMPC's Green Island Hydroelectric Project on the Hudson River. See the following description of the Green Island project for further information.

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3.0 GREEN ISLAND DAM

Biological testing of a prototype MIS was conducted during 1995 and 1996 at Niagara Mohawk Power Corporation's Green Island hydro site on New York's Hudson River. The MIS facility was installed upstream of an existing ice sluice gate at the upstream end of the Green Island Project forebay during the summer of 1995. The entrance to the MIS had a trash rack with 8 inch spacing between bars. The screen itself was 5 feet wide by 16 feet long. An effective screen area of about 70 square feet provided a capacity of 150 cfs at an approach velocity of 7.5 fps. The screen was inclined about a horizontal axis from front to rear at an angle of 15°. Transition walls adjacent to the downstream portion of the screen guide fish into the bypass entrance which was 1.0 feet square in cross-section. Bypass flows were discharged into a fish collection area and were regulated by adjusting the height of a bottom-drop gate located at the terminus of the bypass. The field tests also used an array of strobe lights to help direct fish toward the MIS.

Biological tests were conducted at four velocity increments ranging from 2 to 8 fps using a variety of warmwater and coldwater species. Field evaluations confirmed high rates of diversion and survival for all fish tested except blueback herring. Diversion and survival rates for juvenile migratory rainbow trout [3.7 in (95 mm) average length] were 100 % at velocities less than or equal to 6 fps and 99.3 % at approach velocities of 8 fps. The tests confirmed a relationship between diversion and survival and test velocities. Higher velocities resulted in lower diversion and survival rates.

At the conclusion of the EPRI field tests, Niagara Mohawk and New York State Energy Research and Development Authority decided to conduct additional fish passage tests at the Green Island MIS. These independent tests reportedly confirmed the success of the MIS, documentation of the independent tests has been requested. The EPRI is now seeking interest in a full-scale application of the screen at an existing water intake.

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4.0 HOWARD HANSON DAM

A modular inclined screen (MIS) screen with a capacity of 1,250 cfs at a velocity of 7.8 fps is proposed at Howard Hanson Dam (HHD) to provide downstream passage of anadromous salmonids on the Green River, Washington. The HHD Project is a flood control and flow augmentation project constructed in the early 1960's without downstream fish passage. The new fish bypass design was developed as part of a water supply/fish restoration proposal to provide additional flow downstream of HHD during the summer low-flow period by storing additional water in the spring behind the existing dam.

The proposed downstream fish passage facility consists of a new intake tower with semicircular trashrack, a floating collection horn and MIS chamber, a fish bypass lock and connections between new outflow conduits with the existing flood control outlet conduits.

Selection of the MIS design was the result of a five year evaluation process involving a Fish Passage Technical Committee (FPTC) of state, federal and private fish passage engineers and biologists and Corps of Engineers personnel. A list of 39 criteria were established to guide design of the fish passage facility. Hydraulic features of the proposed design were required to meet criteria for flow characteristics, residence time limits, attraction, predation limitations, and screening velocities.

The flow capacity of the MIS screen will range from 410 cfs at a velocity of 2.56 fps to 1,250 cfs at 7.8 fps. Maximum capacity is 1,600 cfs at 10 fps. The FPTC proposed to limit operation to less than 7.8 fps until prototype operation proves that higher velocities will not result in unacceptable injury rates of fish. Screen area when in the screening position is about 410 square feet, resulting in a normal velocity of 1 fps at 410 cfs to about 3.0 fps at 1,250 cfs. Head loss through the screen was assumed to be about the same as that measured at the Puntledge Eicher screen and Elwah Eicher screen installations. The proposed screen will be rectangular in shape and will be contained in a chamber about 30 feet long, 16 ft wide, and 10 feet high. The screen will be inclined about a horizontal axis from front to rear at an angle of about 16°. The screen composition will be wedgewire with 0.12 inch (3mm) openings.

Under normal operating conditions, fish will be swept up to the center top section of the screen and into a 2-foot by 2-foot bypass entrance leading to a 24 inch diameter low pressure bypass conduit. Operating capacity of the fish bypass entrance section is from about 10 cfs at 410 cfs to about 40 cfs at 1,600 cfs, or roughly 2.5 percent of the total flow into the MIS chamber. Bypass entrance velocities range from 2.5 fps at 10 cfs to about 10 fps at 40 cfs. A minimum entrance velocity of 5 fps was established as a design criterion, but can't be maintained at MIS flows less than 800 cfs without violating bypass entrance acceleration criteria. Velocities through the 24 inch diameter bypass conduit range from 3.2 fps at a MIS screen flow of 410 cfs to 12.4 fps at 1,600 cfs.

Physical and numerical computer models will be developed to assess approach flow characteristics into the proposed fish bypass intake structure to verify hydraulic efficiency and acceleration patterns into the trashrack and collection horn. A scale model will be constructed to test the MIS screen chamber configuration and develop the preferred geometry to ensure greatest fish survival. Modeling of the fish passage facility will begin in 1998 and construction is expected to be completed by 2003.

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5.0 PUNTLEDGE PROJECT

Two Eicher screens were constructed and installed at the Puntledge River Hydro Intake Facility in 1993. Each screen, with the capacity of 520 cfs at 6 fps, was developed to provide downstream passage of anadromous salmonids in the Puntledge River near Courtenay, British Columbia. The screens were an attempt by B.C. Hydro to revitalize the stocks of steelhead trout and chinook, coho, pink, and chum salmon that have been declining since the intake facility was reconstructed in 1958. The reconstruction of the hydro facility expanded the intake structures from 300 to 970 cfs and included the installation of a Francis turbine. As a result, entrainment of anadromous salmonid smolts in the turbine was estimated to be as high as 58%. The Eicher screens were installed after a series of behavioral devices (i.e., underwater hammer, submerged strobe light, steel chain curtain, and graduated field fish guidance system) failed to divert smolts away from the turbine.

The Eicher screen, considered to be the most efficient and cost effective alternative, was installed during the winter and spring of 1993. In order to reduce penstock velocities from 8 to 6 fps, the existing penstock (12 ft diam.) was retrofitted with two smaller (10.5 ft diam.) penstocks. The screens were fabricated to meet the design criteria developed by representatives of Department of Fisheries and Oceans, National Marine Fisheries Service, and individuals involved in the design and evaluation of the Elwha Dam facility. The design criteria were selected to pass 1.5 inch (35 mm) chinook fry. The screen was composed of Johnson wedgewire material with 0.1 inch (2.5 mm) bar spacing to achieve 58% porosity. The elliptical-shaped screens were set at a 16.5° angle to flow in each penstock. The bypass pipes (24 in diam.), with the ability to carry 25.2 cfs at 6 fps maximum approach velocity (8 fps bypass velocity), is approximately 5% of the penstock capacity. In addition, design criteria called for a minimum of a 3:1 ratio of sweeping velocity (velocity parallel to the screen) to normal velocity (velocity perpendicular to the screen) and \pm 20% maximum variation of normal velocity from the mean normal velocity to avoid impingement in "hot spots".

While in operation, fish enter intakes 3 and 4 and travel through a 8.5 ft diameter pipe to the penstock before encountering the 42 ft long Eicher screen. The bypass pipes lead to an evaluation facility which is composed of an energy dissipation tank, wolf traps, collection tanks, and evaluation tank, holding tanks, downwell, and an outfall pipe to the Puntledge River below the diversion. The collection facility has the capacity to sample either, but not both, of the two screens. The bypass pipe not routed through the collection facility is diverted directly into the downwell and the fish are released back into the river.

Results of the biological evaluation conducted during 1993 and 1994 indicate that the Puntledge River Eicher screens provide bypass rates of 100% [steelhead smolts; 10.4-12.2 in (264-310 mm) average length], 96% [sockeye smolts; 3.8-6.1 in (97-155 mm) average length], and 96% [chum fry; 1.6-2.1 in (41-53 mm) average length]. In addition, chinook smolts [2.7-4.5 in (69-114 mm) average length] were passed at a 80% bypass rate while 89% of the coho smolts [3.3-5.3 in (84-135 mm) average length] were diverted away from the turbines in 1994. Sockeye smolts were the most vulnerable to descaling when diverted through the facility. Twenty percent of sockeye were classified as descaled (based on the Columbia River Scale Loss Protocol), while only 3.8% and 5.3% of coho and chinook were classified as descaled, respectively.

The screen was set to clean (backwash) once every 4 hours during the 1993 and 1994 evaluation. Based on an unreported cycle time, estimated fish guidance efficiency during cleaning was 1.25%. Fish passing through at this time would suffer approximately 58% mortality. Because this facility is situated below Comox Lake (67,000 acre feet storage capacity), a boom located at the Comox Lake Dam captures a large percentage of the debris passing through the system. Trash racks, with 2 inch bar spacing, located at the openings of intake 3 and 4 capture the majority of the remaining large debris. Small twigs, grass, and leaves pass into the penstock and onto the screen, with the majority passing through to the bypass pipe and into the river. Small head losses, causing decreases in fish bypass efficiency, were noticed when debris were lodged in the screen.

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6.0 UNIVERSITY OF WASHINGTON - 1987 HYDRAULIC MODELING

A physical model of an Eicher screen was evaluated in a recirculating flume at the University of Washington Harris Hydraulics Laboratory in Seattle, Washington during 1984 and 1985. Unlike conventional screens, Eicher screen technology involves approach velocities greater than the sustained swimming speed of juvenile outmigrants. When a fish encounters an Eicher screen, they are swept across the screen face within a few seconds. An Eicher screen had been installed at the T.W. Sullivan Plant at Willamette Falls, Oregon; and while results were promising, some descaling and other fish injuries were observed. Testing at the Harris Hydraulics laboratory was conducted to evaluate local hydraulic conditions, screen types, screen spacing, and velocity vectors on fish bypassing the screen.

The Plexiglass model consisted of six components: an upstream head; a transition section for fish entry; a test section containing the Eicher screen; a bypass/outflow section; a collection tank; and a weir tank for measuring bypass flow. Velocity profiles were measured at several locations along the conduit in order to evaluate the effect of the screen on flow and head loss across the screen. A video camera was used to film rainbow trout [2.5-5.0 in (64-127 mm) average length], coho [5 in (127 mm) average length], chinook [4 in (102 mm) average length], and steelhead smolts [5 in (127 mm) average length] passage over the screens, and scale loss was measured on fish that touched the screen.

Johnson and Hendrick wedgewire screens and a perforated plate screen, with porosities ranging from 0.04 inch (1 mm) to 0.12 inch (3 mm), were inclined at 10.5°, 15.5°, and 30° to the flow. Both Johnson and Hendrick wedgewire screen with 0.08 inch bars (2 mm) and 0.08 inch (2 mm) spacing between bars provide satisfactory passage with appropriate velocities. Hendrick wedgewire has a flatter profile which results in better debris passage. Fish passage was successful for all species and sizes of fish tested at three screen angles when average test section velocity was greater than 5 fps and bypass velocity was greater than 20% of the average velocity in the test section.

The rate of fish impingement on the screen decreased as the magnitude of the bypass velocity:test section velocity ratio increased. Impingement near the bypass end of the screen was avoided by increasing the bypass velocity to 20% more than the test section velocity. Decreased screen porosity near the bypass end also eliminated impingement. Impingement was most pronounced

when test section velocities were less than 4 fps. Descaling was not significantly different between test and control fish and there was no any delayed mortality (72 hour) for any test fish.

Based on the results obtained from this study, the Electric Power Research Institute (EPRI) undertook a search for a suitable site to test a prototype Eicher screen. The Elwha Dam located on the Elwha River near Port Angeles, Washington was selected on the basis of access to the penstocks and operational flexibility of the project.

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7.0 T.W. SULLIVAN PLANT

An Eicher screen was constructed in a 10 foot diameter penstock at the T.W. Sullivan Plant located at Willamette Falls, Oregon. The Eicher screen has the capacity to screen 450 cfs of water flowing through the penstock down to 50 cfs flowing through the bypass at 6 fps maximum average penstock velocity (1.6 fps maximum approach velocity). The T.W. Sullivan Plant is a run-of-the-river diversion project consisting of 13 turbines with a capacity at full load of 5,200 cfs. The Eicher screen, located in turbine Unit 13, was installed in response to an Oregon Department of Fish and Wildlife study indicating juvenile salmonids experience mortality ranging from 8%-12% (in 12 Kaplan turbines) to 14%-26% (in 1 Francis turbine) at the T.W. Sullivan Plant. From 1980 through 1992, multiple changes were made on the initial facility to increase guidance efficiency and decrease injuries. However, since 1992, the T.W. Sullivan migrant bypass system has remained virtually unchanged.

Since 1992, the configuration of the downstream migrant bypass system at the T.W. Sullivan Plant has consisted of three major components; the forebay guidance system, the turbine bypass system (Eicher screen), and the fish evaluator system. Outmigrant fish pass through the forebay and by the first 12 intakes via a series of modified trash racks that act as louvers. The trash racks have bar spacing ranging from 1 inch (units 1-3) to 1.5 inches (units 4-12) and are constructed of flat bars. The outmigrant fish enter unit 13 through trash racks constructed of flat bar, but with 5 inch bar spacing to reduce fish injury and encourage fish movement into the unit. All trash racks were realigned from the original configuration to eliminate sharp angles, while a training wall was added opposite of the units in the forebay to provide laminar flow through the trash racks.

After entering unit 13 penstock (10 ft diam.), fish proceed downstream for 21 feet to a series of Eicher screens. Two Eicher screens, both constructed of 0.08 inch (2 mm) wedgewire material with 0.08 inch (2mm) openings are placed in a "hump-back" configuration. The first screen section is placed at a 19° angle to flow and can be rotated 33° to clean. The downstream screen section is fixed permanently in a slightly downward sloping direction. Original designs called for a

single screen set at a 19° angle to flow. The two screens were made necessary because of limited space inside the penstock. After passing the fixed screen, fish exit the penstock through a rectangular bypass conduit (30 in high by 36 in wide) which expands to 90 inches wide before passing over a control gate (129 in wide). Water velocity in the bypass remains the constant with the velocity of the water in the penstock (6 fps). From the bypass, fish fall into a large plunge pool and are diverted into a fish evaluation facility via the discharge channel. The bypass system is designed to carry 50 cfs (11.1% of penstock discharge) when average penstock velocity is 6 fps.

The fish evaluation system is designed divert 36 cfs of water through a spillway chute into the tailrace by way of a bar screen, while the fish and 14 cfs of water pass down the test channel, over an inclined screen, and into a pipe (6 in diam.) that drains into the holding box. Thus, fish finding their way into the holding box have successfully passed through five screens (including the trash racks).

Numerous species have successfully passed through the T.W. Sullivan downstream migrant system. Average guidance efficiency for all spring chinook [5.5-11.6 in (140-295 mm) average length] combined is 90%, while fall chinook [3.5-5.9 in (89-150 mm) average length] guidance efficiency is 82%, and steelhead [6.3-11.4 in (160-290 mm) average length] guidance efficiency is 82% for all tests combined. There was no correlation between size of the fish tested and fish guidance efficiency. Descaling (> 20% descaled on one side) has ranged from 0.48% (steelhead) to 3.9% (spring chinook) in 1991-1992. Latent mortality (48 hour) was 1.32% (spring chinook), 2.05% (fall chinook), and 0.32% (steelhead) since 1993.

Pressure difference (head loss) across the screen is monitored continuously at the Eicher screen. When head loss reaches 18-20 inches, the screen is rotated into back flushing (cleaning) position. During the cleaning cycle, the load to unit 13 is reduced to 5% which limits the number of fish entering the penstock. The total cleaning sequence, including reducing the load on Unit 13 to 5%, takes approximately 19 minutes to complete. During heavy debris loading events, the screen may need to be cleaned once per hour. From early spring through fall, the screen will operate for extended periods without cleaning.

The T.W. Sullivan Plant is currently operated by Portland General Electric. Portland General Electric believes that they have lowered juvenile outmigrant salmon mortality from around 11% to a present day level of less than 3% with minimal annual costs. Evaluation of survival through the plant will continue in the future.

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References

Cramer, D. 1997. Evaluation of a louver guidance system and Eicher screen for fish protection at the T.W. Sullivan plant in Oregon. Presented at the Fish Passage Workshop. Milwaukee, Wisconsin. 14 pp.

8.0 WYNOOCHEE DAM

Construction of an Eicher screen at Wynoochee Dam will increase the survival of outmigrating juvenile salmonids as part of a proposed Section 1135 project. Wynoochee Dam was constructed in 1972 to provide water supply, flood control and flow augmentation for downstream fish enhancement. A hydropower facility was added to the project under terms of a Federal Energy Regulatory Commission license issued in 1987. Originally constructed and operated by the U.S. Army Corps of Engineers, operation of the project was transferred to the Cities of Tacoma and Aberdeen, Washington in 1993.

The project is located on the Wynoochee River in Grays Harbor County, Washington. Upstream passage for adult migrants at the project is achieved by a trap and haul facility at RM 49.6. Juvenile outmigrants pass the dam through a multi-level outlet constructed as part of the original project; however, a significant number of salmon and steelhead smolts residualize in the reservoir or are killed passing through the outlet. The hydropower project is presently not operated during the spring smolt outmigration period. Improved fish passage will be gained by retrofitting an Eicher screen to the penstock to move fish out of the penstock into a bypass system for transportation into the Wynoochee River downstream of the project.

A list of 25 biological hydraulic design criteria were developed by staff from the Washington Department of Fish and Wildlife and National Marine Fisheries Service. The criteria included: maximum average penstock flow velocity during Eicher screen operation of 8.0 fps; minimum average penstock flow velocity during screen operation of 2.2 fps; continuous flow acceleration from Eicher screen to fish bypass; minimum 30 inch diameter pressure bypass pipe; and fish bypass pressure pipe average velocity must not exceed 10 fps nor be less than 4 fps. Due to site-specific and hydraulic design constraints, not all criteria will be met; however, agency staff have concurred with design assumptions.

The Eicher screen fish bypass facility will consist of modification to the existing intake trashrack and wet well, the penstock Eicher screen, pressure bypass, telescoping atmospheric pressure relief manifold, downstream bypass and discharge outlet. The Eicher screen will be elliptical in shape and placed in a 40 feet long section of 10 ft diameter penstock located about 100 feet downstream of the dam face. Within the 40 foot penstock section, the screen will be inclined about a horizontal axis from front to rear at an angle of about 16.5°. Screen composition will be

wedgewire with 58 percent screen porosity. The screen is designed to operate at penstock discharges between 200 cfs and 650 cfs. Hydraulic conditions within the penstock during operation of the Eicher screen will be controlled by the powerhouse demand.

A small diameter outlet at the top of the penstock near the downstream end of the Eicher screen passes fish which have been screened from the main flow into a 24 inch diameter pressure bypass pipe. The fish bypass is designed to withdraw an average of 15 to 30 cfs, or roughly 5 to 8 percent of the penstock flow. Bypass discharge is controlled by the hydraulic head differential between the top of the telescoping pipe section and the reservoir. The proposed design will result in a continuous rate of water velocity acceleration at the bypass entrance to draw fish into the pressure pipe; however, the rate of acceleration will be somewhat faster than the desired rate of about 0.1 fps per linear foot of bypass entrance.

A final Feasibility Report and Environmental Assessment was submitted to Headquarters US Army Corps of Engineers in January 1997; construction is scheduled to be completed by September 1998. Details of the biological and hydraulic design criteria are contained in Appendix G of the final Feasibility Report.

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References

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9.0 PINE COULEE HYDRAULIC MODEL USING THE ICHTHYOHYDRAULICS MOBILE EXPERIMENTAL FLUME

The Department of Fisheries and Oceans in Canada is currently working on a comprehensive national guideline for screening and guidance of fish in large water volumes. They are considering high velocity screens as an acceptable option but intend to conduct their own assessment of fish responses to high velocity screens. They also want to develop better approach velocity criteria for species with limited available information. Tests of a prototype high velocity inclined screen

for the new Pine Coulee irrigation canal are scheduled for the summer of 1997. Tests will be conducted using the Ichthyohydraulics Mobile Experimental Flume (IMEF).

The IMEF is a device developed in Newfoundland for conducting experiments on fish swimming performance and evaluating screens and other bypass options. The IMEF consists of five detachable components for ease of transportation. Two components, each almost 33 feet in length, make up the rectangular testing channel. The inlet tank, the outlet tank and the pump skid are the other three components. The flume testing section located between the tanks is 64 feet in length, 3.3 feet in width and 4 feet in depth. The inlet and outlet tanks are 8 ft by 8 ft in plan and each contains a fish holding compartment. A variable speed diesel powered pump capable of circulating up to 172 gallons per second of water between the two tanks controls the flume discharge. One side of the flume is constructed from clear lexan to allow visual observations.

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10.0 INTAKE SCREENING OF NON-VOLITIONAL MIGRANTS

The United States Congress enacted the Federal Water Pollution Control Act in 1972 “to restore and maintain the chemical, physical and biological integrity of the Nation’s waters”. Provisions of the Act governed cooling water intake structures (Section 316(b)) and resulted in studies of the survival of aquatic organisms entrained or impinged at power generating stations in coastal estuarine, marine and freshwater systems. Evaluation of the swimming performance of entrainable organisms led to improved design of water intake structures. Many of the cooling water intake structures were designed using approach velocities higher than existing NMFS criteria; however, approach velocities were typically less than 1.0 fps and are not considered high velocity technology. A brief review of Section 316(b) studies pertaining to the swimming performance of juvenile salmonids is contained in Task 2(B) of this report.

11.0 SUBMERSIBLE TRAVELING SCREENS (STS)

Extensive hydraulic model, prototype and full-scale tests of STS technology have been conducted at Columbia Basin hydropower projects. Submersible traveling screens are considered low-velocity technology even though they involve velocities higher than existing NMFS criteria for

conventional screening facilities. We did not include literature describing the results of hydraulic and biological evaluations of STS facilities in this review.

12.0 GENERAL REVIEWS OF FISH BYPASS TECHNOLOGY

Several substantial reviews of downstream migrant fish protection technologies have been conducted since the mid 1980's. Most of the reviews include summaries and evaluations of behavioral and physical barriers, collection systems and diversion systems. All of the documents describe the status and relative success of high velocity screening studies available at the time of the review.

A common lament noted in the reviews and pertinent to this project is that much of the research has not been reported in the peer-reviewed scientific literature, but appears in progress reports for specific projects. Authors of the reviews note that often research is not described in sufficient detail to allow thorough analysis of the results. The reviewers consistently acknowledge the promising nature of high velocity technology but suggest widespread acceptance may require several statistically robust, repeatable experiments of the fish species and size range of interest.

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